



INTEGRATED FORECAST AND MANAGEMENT IN NORTHERN CALIFORNIA – INFORM

A Demonstration Project – Phase II

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GEORGIA WATER RESOURCES INSTITUTE

Purpose

- Increase efficiency of water use in Northern California using climate, hydrologic and decision science

Goal and Objectives

- Demonstrate the utility of weather & climate and hydrologic forecasts for water resources management in Northern California
- Implement integrated forecast-management systems for the Northern California reservoirs using operational weather & climate forecast data
- Perform tests with actual data and with management input

SPONSORS-COLLABORATORS

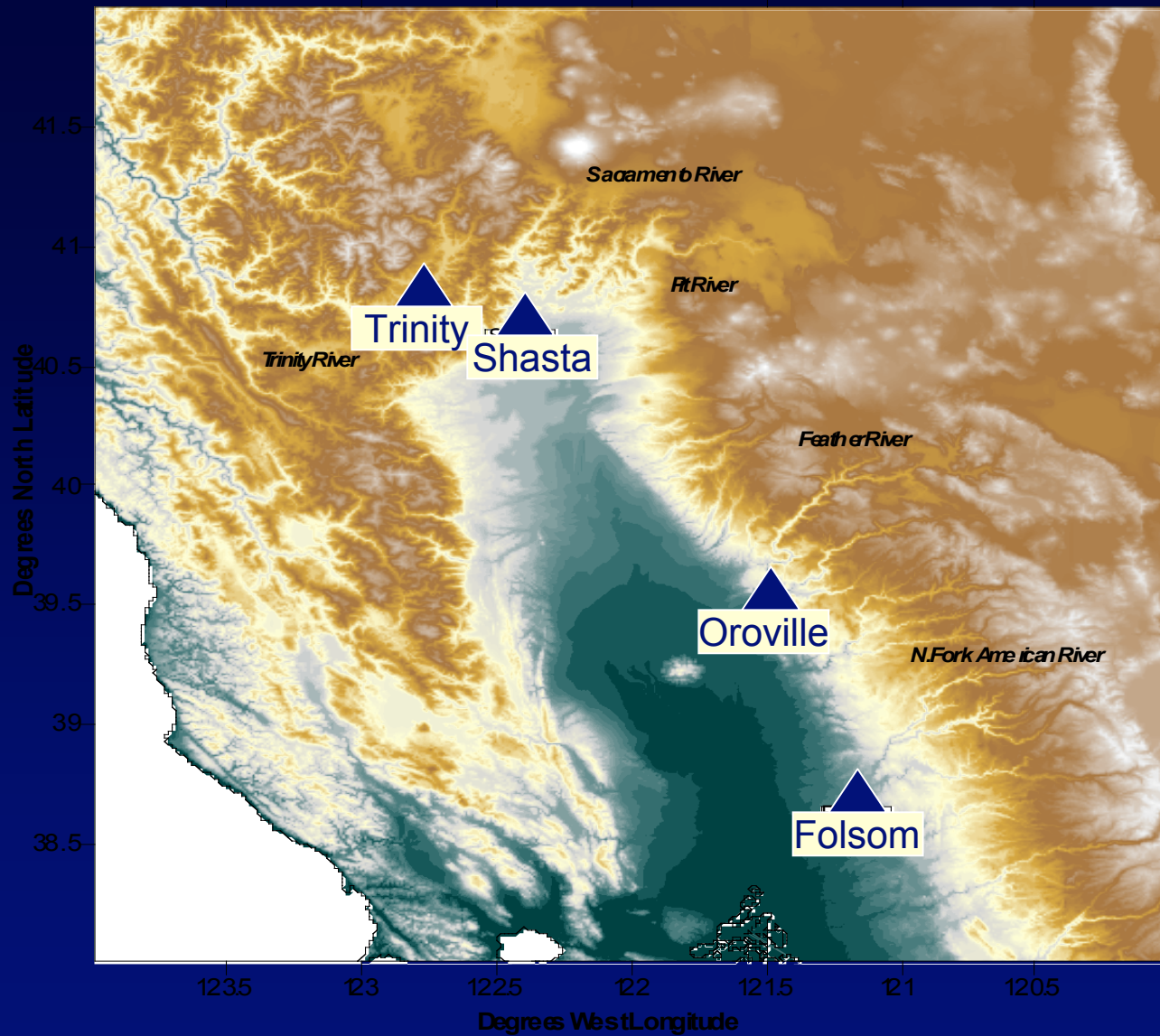
Sponsors:

CALFED Bay Delta Authority
California Energy Commission
National Oceanic and Atmospheric Administration

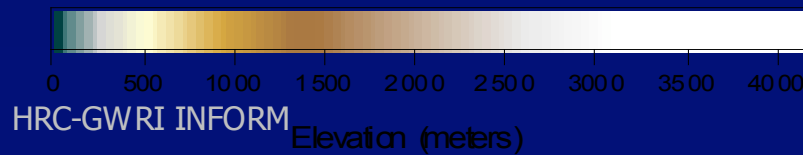
Collaborators:

DWR - California Department of Water Resources
CNRFC - California-Nevada River Forecast Center
SAFCA - Sacramento Area Flood Control Agency
USACE - U.S. Army Corps of Engineers
BoR - U.S. Bureau of Reclamation

Major Reservoirs in Northern California



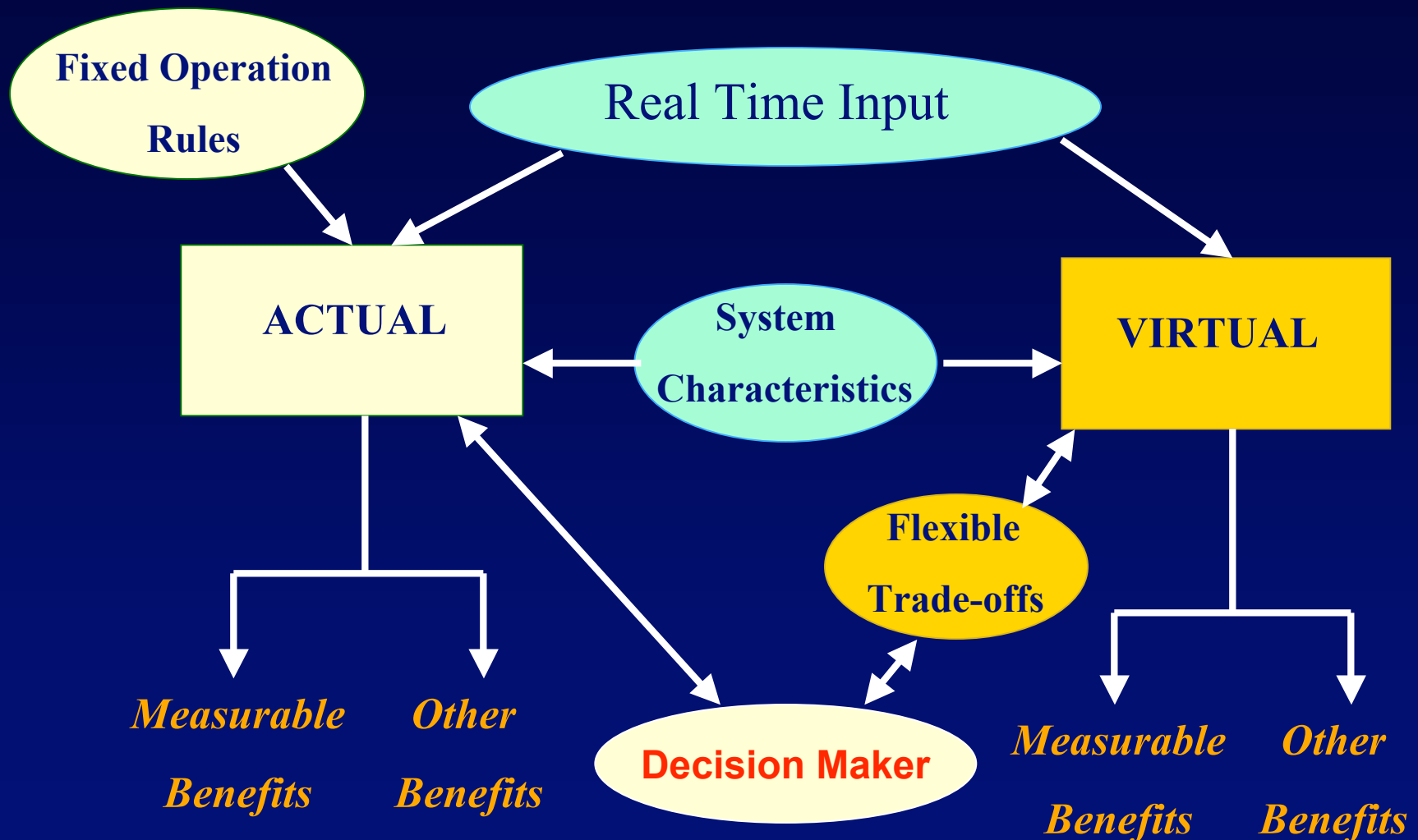
Application Area

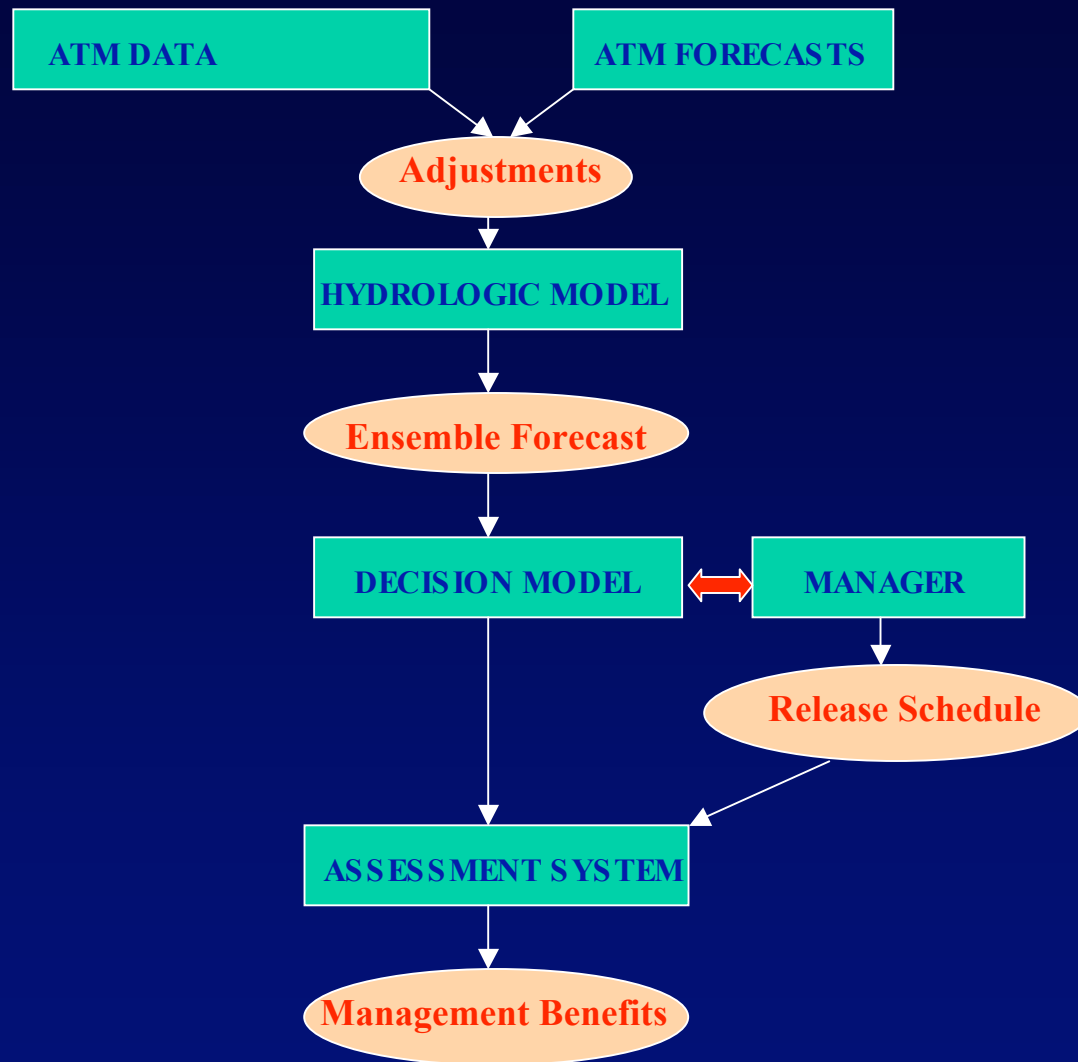


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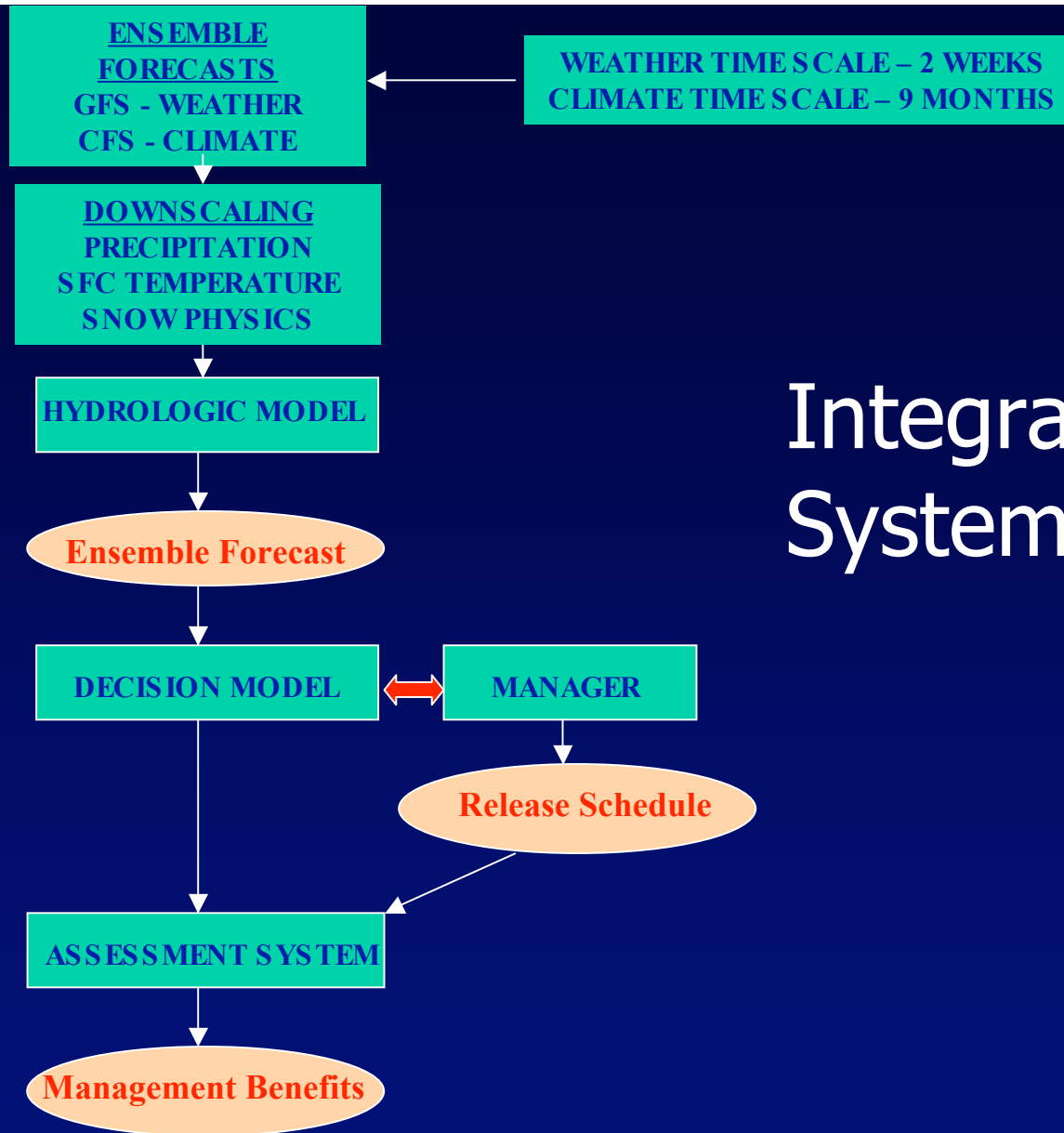
9/15/2005

Demonstration Concept





Integrated System Diagram

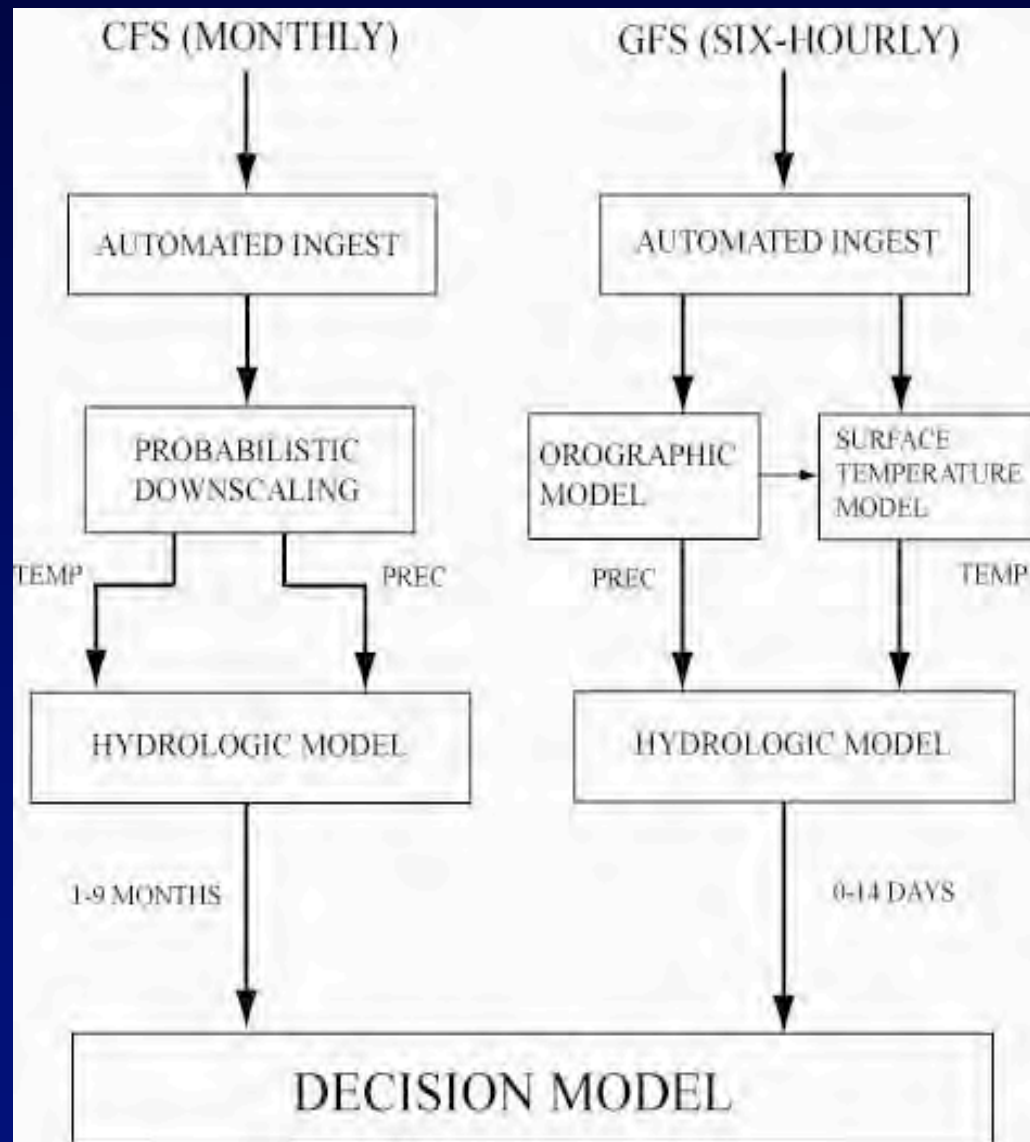


Integrated System Diagram

Phase 2 (2004 – 05)

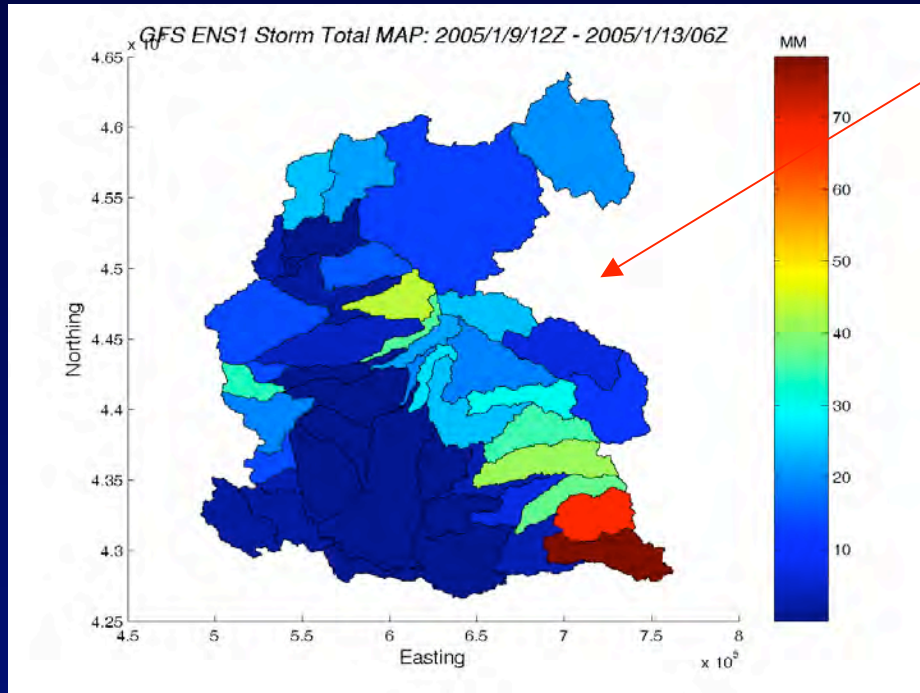
- Design and tests of ensemble weather forecast (GFS) ingest component and links to downscaling components
- Regional validation of precipitation downscaling
- Design, implementation and validation of sfc temperature & snow physics modules
- Validation of hydrologic forecast component for the major reservoir drainage areas
- Development and testing of an integrated monthly simulation and planning model for the entire INFORM region

INFORM System Climate and Weather Data Components and Links

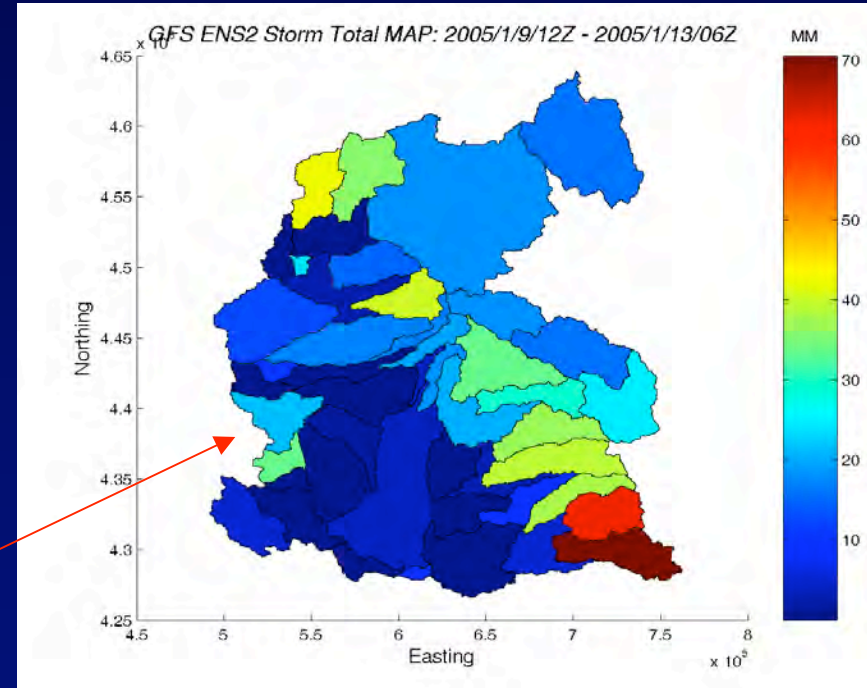


GFS Driven Mean Areal Precipitation: Software Tests

Ensemble 1 (of 10)



Ensemble 2

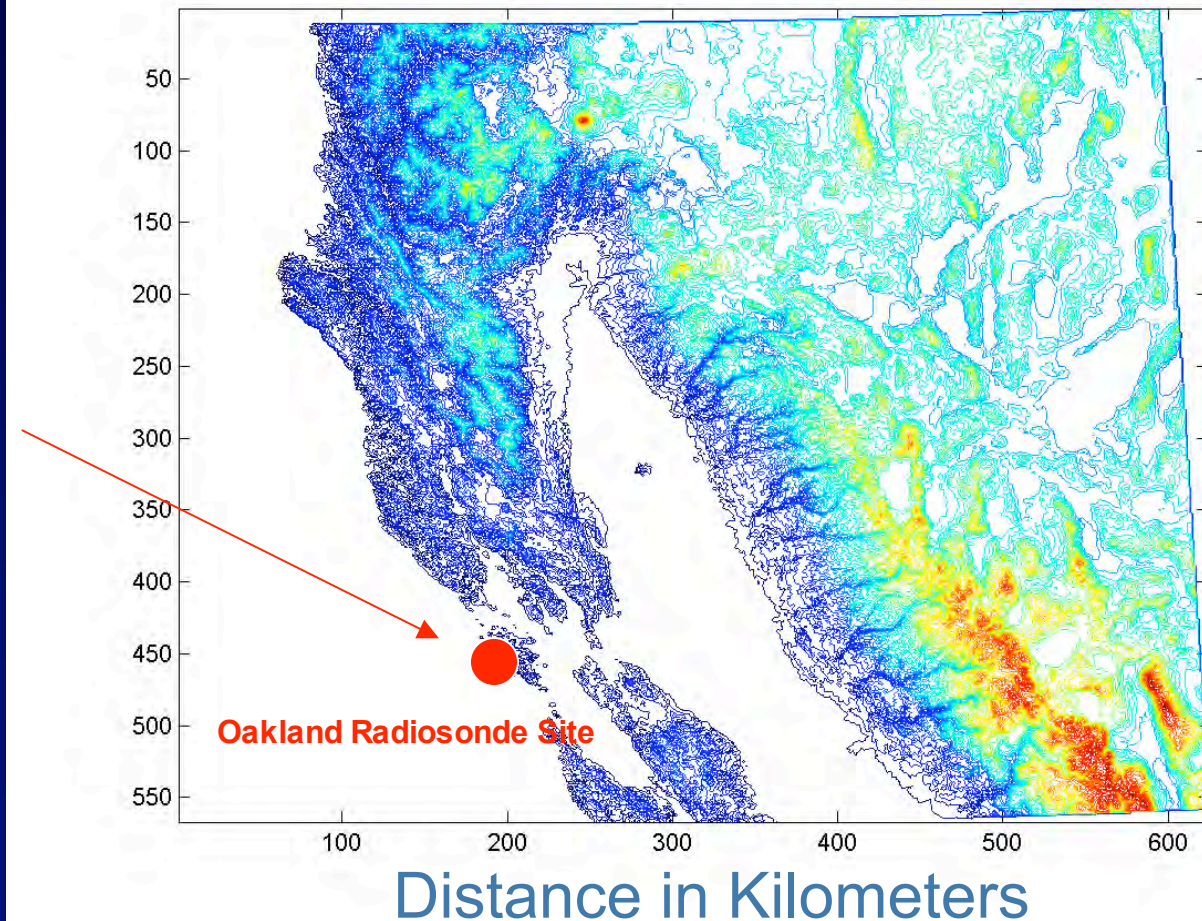


Precipitation and Temperature Downscaling - Domain

Test Period

**Nov – May
1969 – 2004**

**NCEP Global
Reanalysis Forcing**



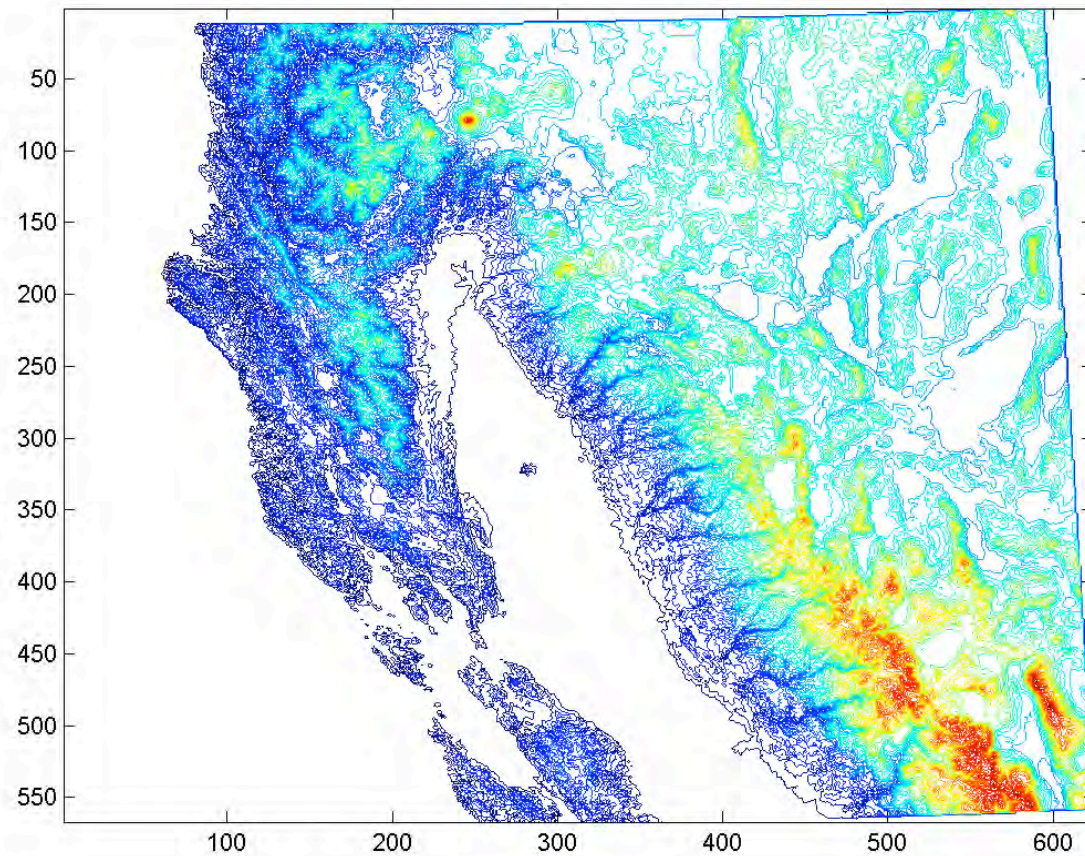
Precipitation and Temperature Downscaling Domain

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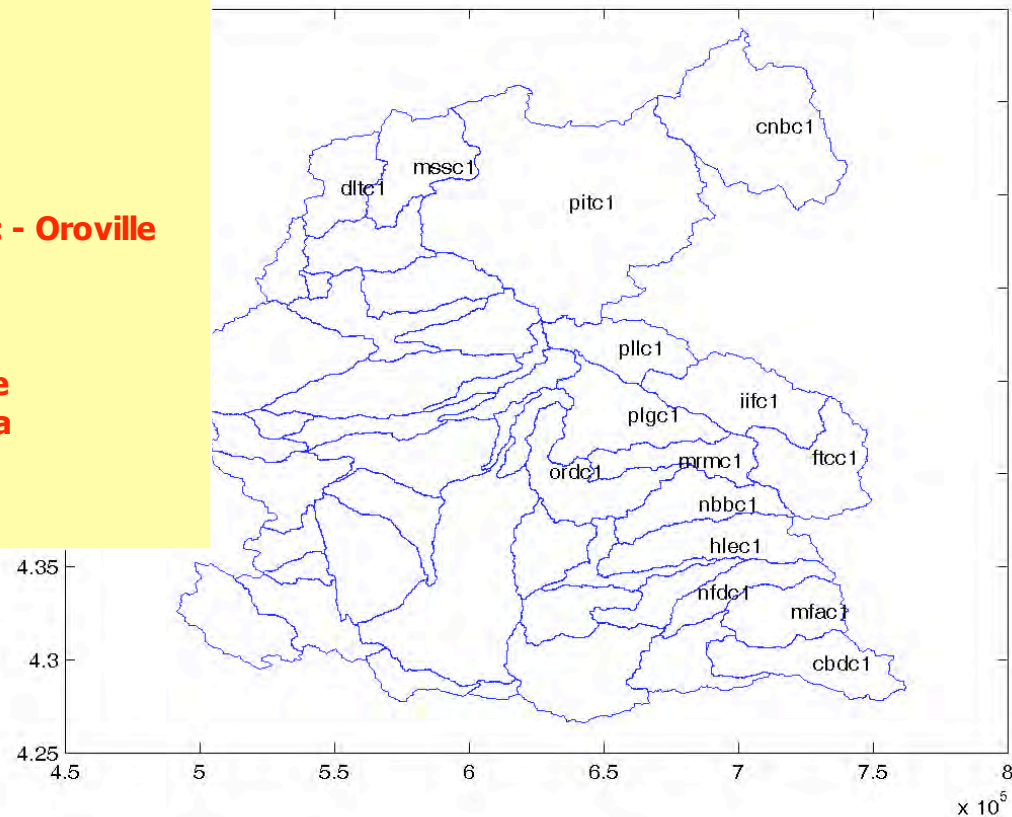
10 km resolution



Distance in Kilometers

Precipitation Downscaling – Regional Validation

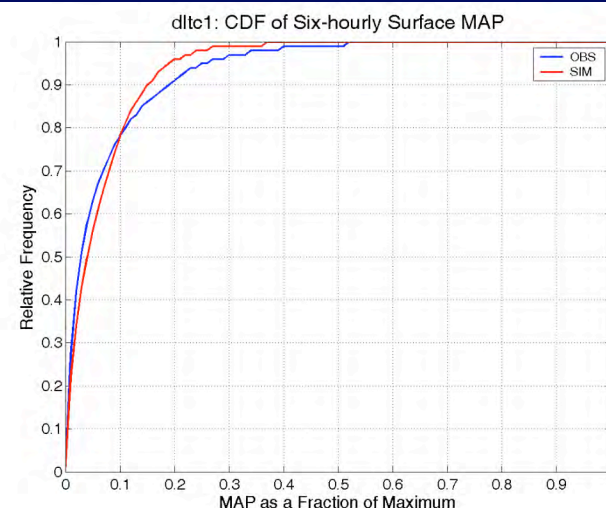
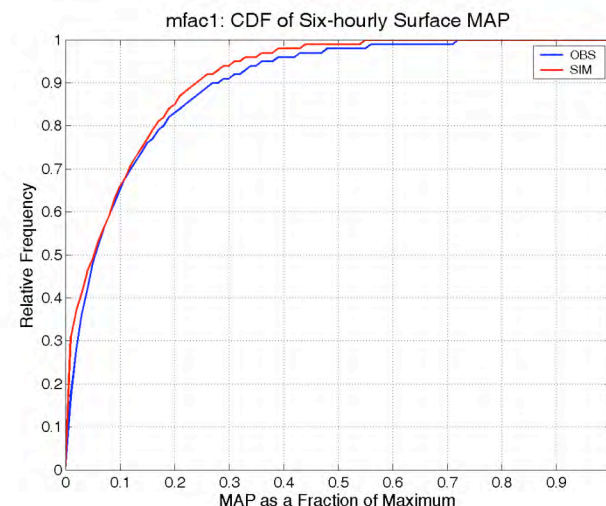
cbdc1: South Fork, American River - Folsom
cnbc1: Pit River at Canby - Shasta
dlfc1: Sacramento River at Delta - Shasta
ftcc1: Middle Fork feather at Clio - Oroville
hlecl: South Yuba River
iifc1: Indian Creek - Oroville
mfac1: Middle Fork, American River - Folsom
mrnc1: Middle Fork Feather River at Merrimac - Oroville
mssc1: McCloud River - Shasta
nbbc1: North Yuba River
nfdc1: North Fork, American River - Folsom
ordc1: Local Feather River at Oroville - Oroville
pitc1: Pit River at Montgomery Creek - Shasta
plgc1: North Fork Feather River - Oroville
pllc1: Lake Almanor drainage - Oroville



Precipitation Downscaling – Performance Measures

Southwesterly 700mbar Wind @ SimPrec > 1 mm/6hrs

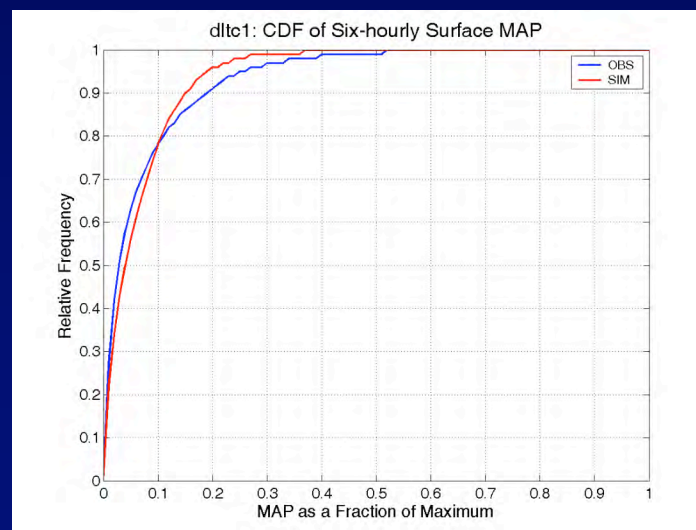
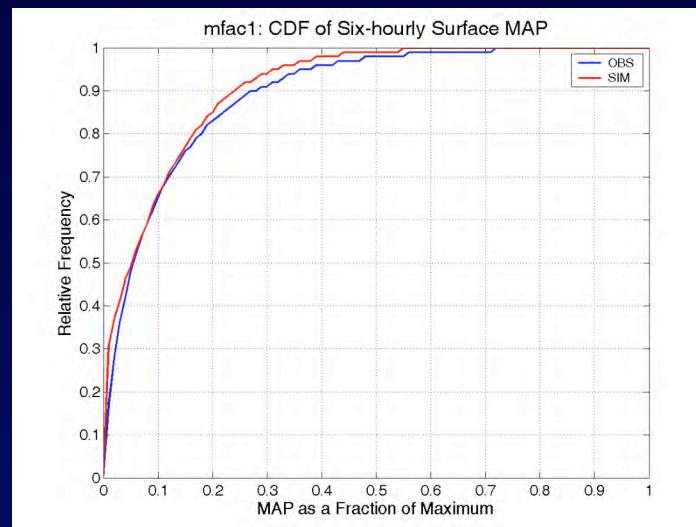
<i>BASIN</i>	<i>AV-OBS</i>	<i>STD-OBS</i>	<i>AV-SIM</i>	<i>STD-SIM</i>	<i>CC-S/O</i>
cbdc1	2.70	6.36	5.86	7.87	0.66
cnbc1	0.59	1.24	1.84	1.72	0.36
dltc1	3.94	1.85	7.25	3.11	0.38
ftcc1	1.53	0.90	3.97	1.61	0.59
hlecl	3.58	4.39	7.16	5.58	0.69
iifc1	1.85	1.10	4.12	2.24	0.48
mfac1	3.22	6.46	6.71	8.27	0.68
mrmc1	3.64	3.87	7.15	5.10	0.62
mssc1	4.05	1.74	7.56	2.97	0.40
nbbc1	4.11	4.35	8.08	5.61	0.66
nfdc1	3.09	4.55	6.43	5.92	0.67
ordc1	4.34	3.58	8.49	4.92	0.53
pitc1	1.56	1.15	3.30	1.53	0.48
plgc1	3.40	2.75	6.80	3.90	0.54
pllc1	2.43	2.32	5.13	3.15	0.56



Precipitation Downscaling – Performance Measures

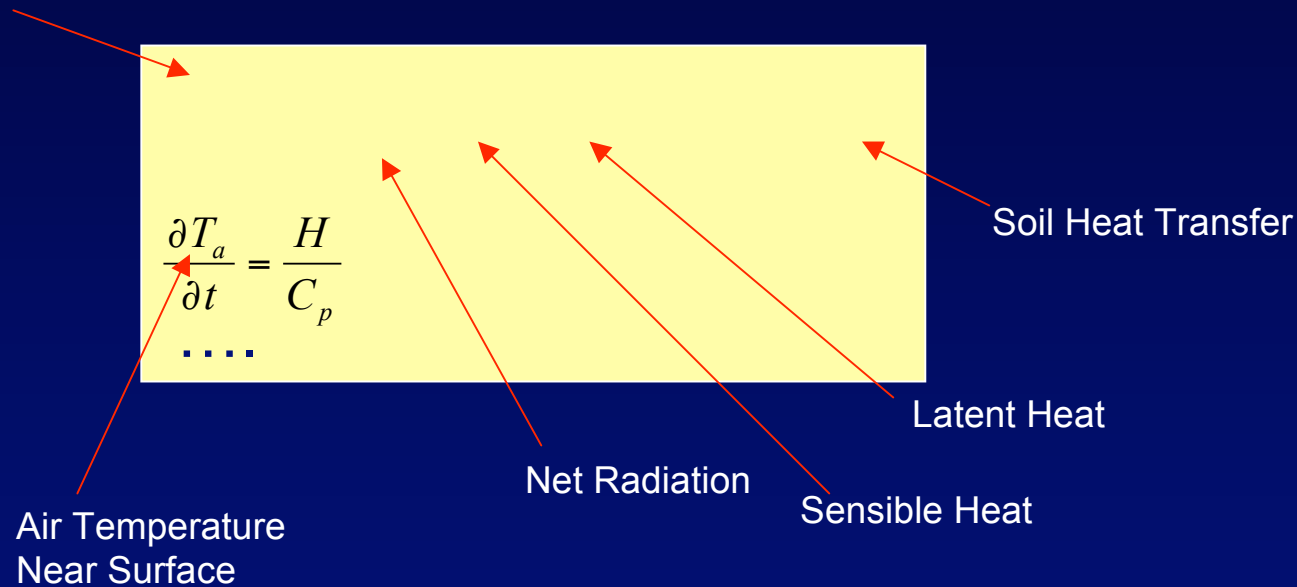
Cases with SW 700 mb Winds
And Simulated Ppt > 1 mm/6hrs

<i>BASIN</i>	<i>CC-S/O</i>
cbdc1	0.66
cnbc1	0.36
dltc1	0.38
ftcc1	0.59
Hlec1	0.69
iifc1	0.48
mfac1	0.68
mrmc1	0.62
mssc1	0.40
nbbc1	0.66
nfdc1	0.67
ordc1	0.53
pitc1	0.48
plgc1	0.54
pllc1	0.56



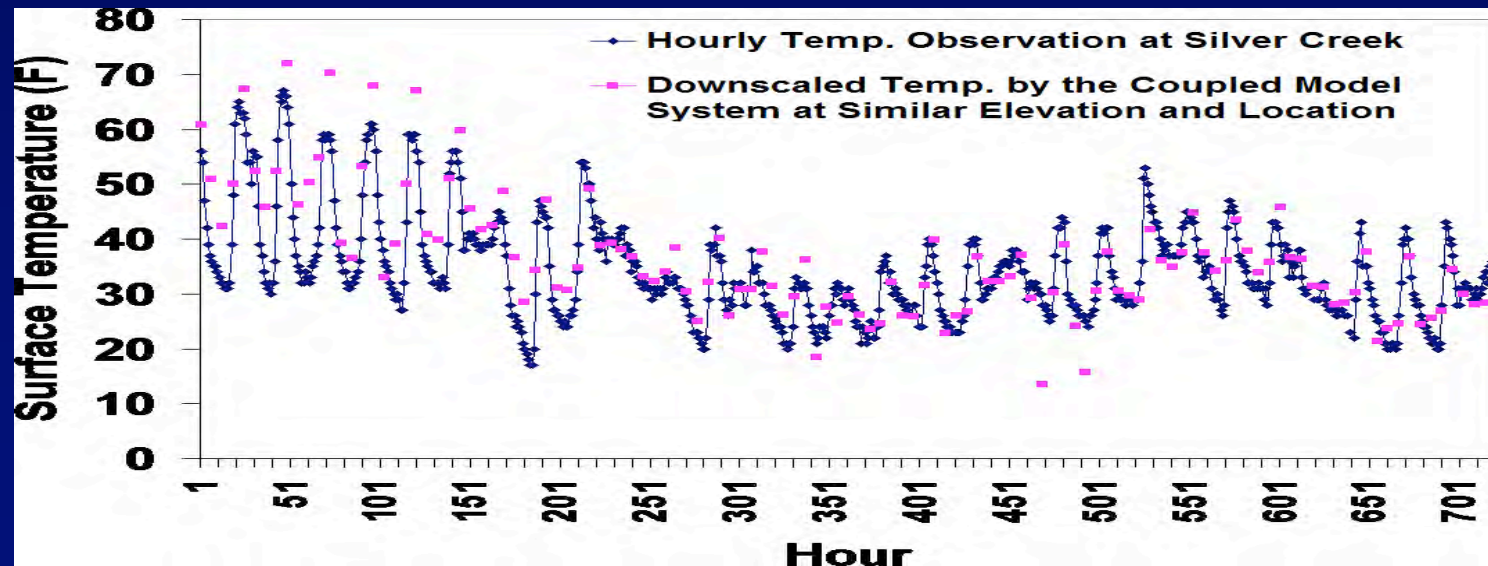
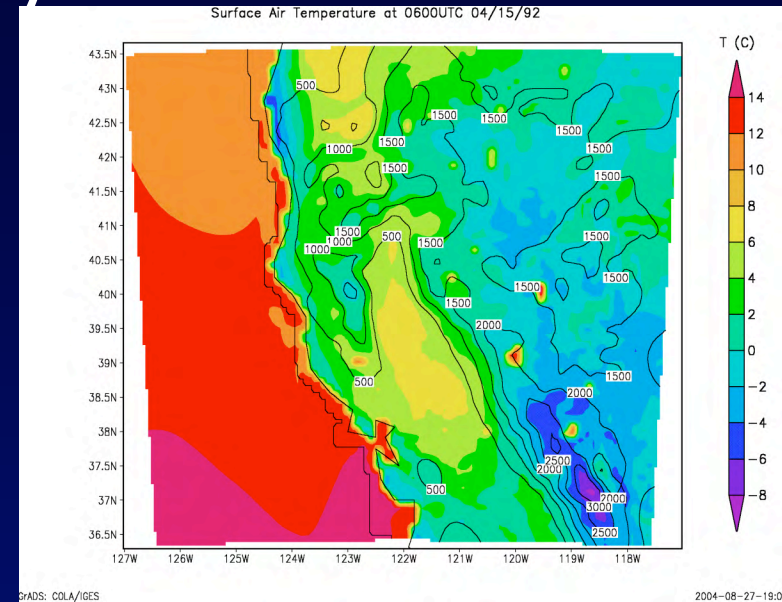
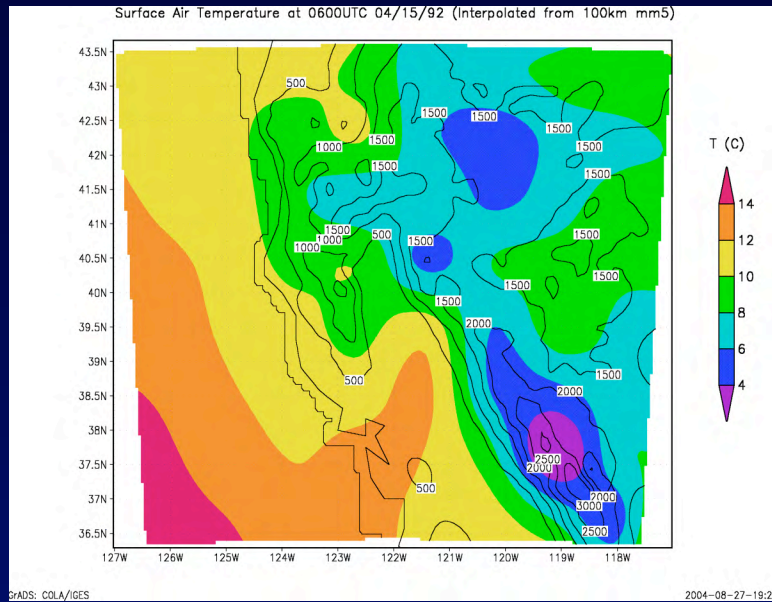
Temperature Downscaling - Model

Ground Surface
Temperature

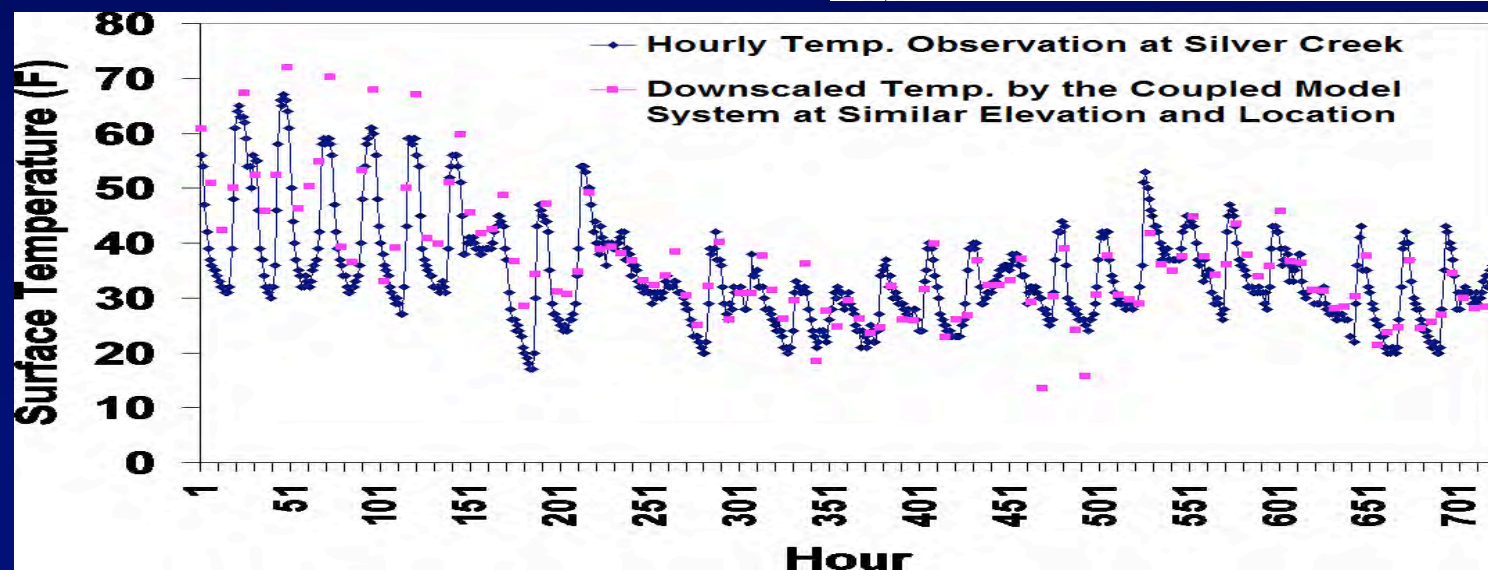
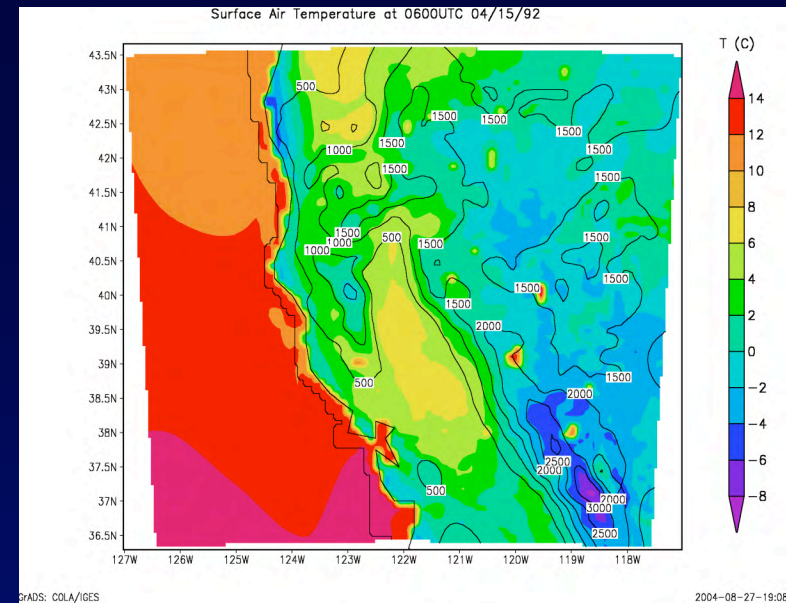
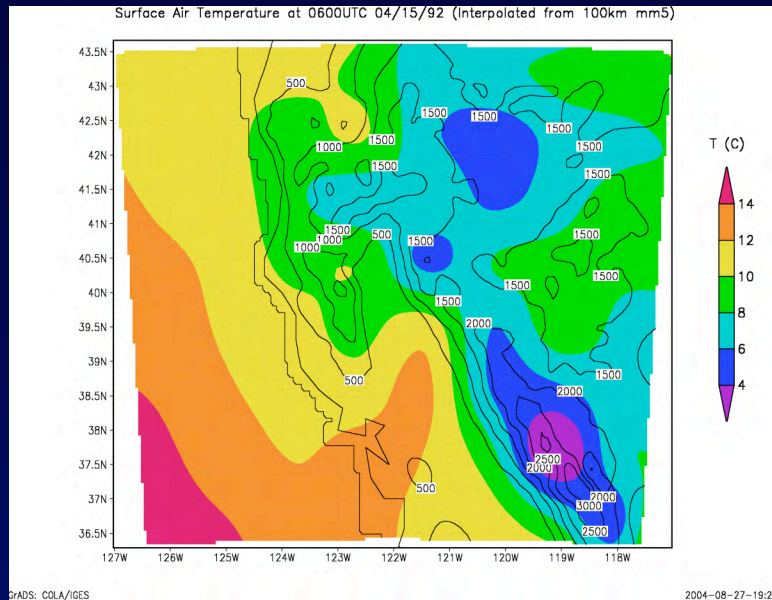


$$H = \rho_a C_p C_{dh} V_a (T_s - T_a)$$

Temperature Downscaling – Preliminary Tests

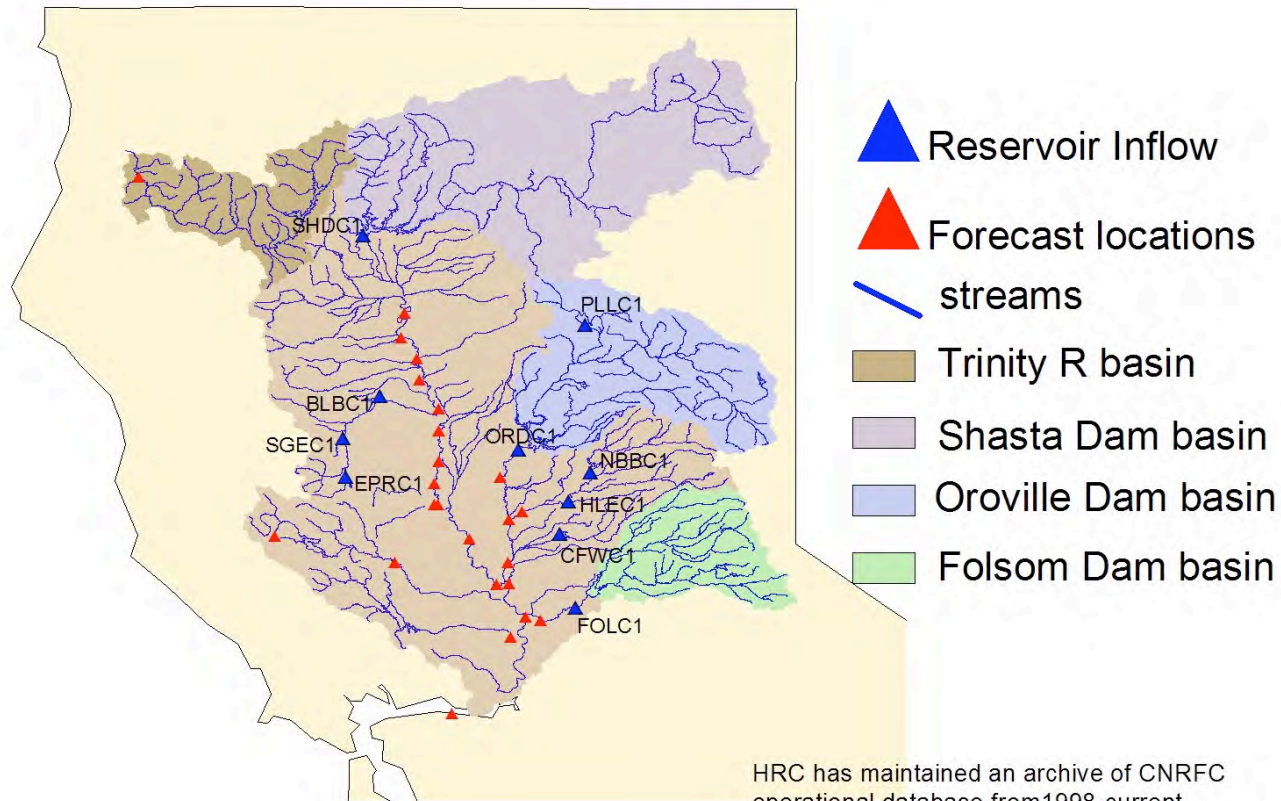


Temperature Downscaling – Tests

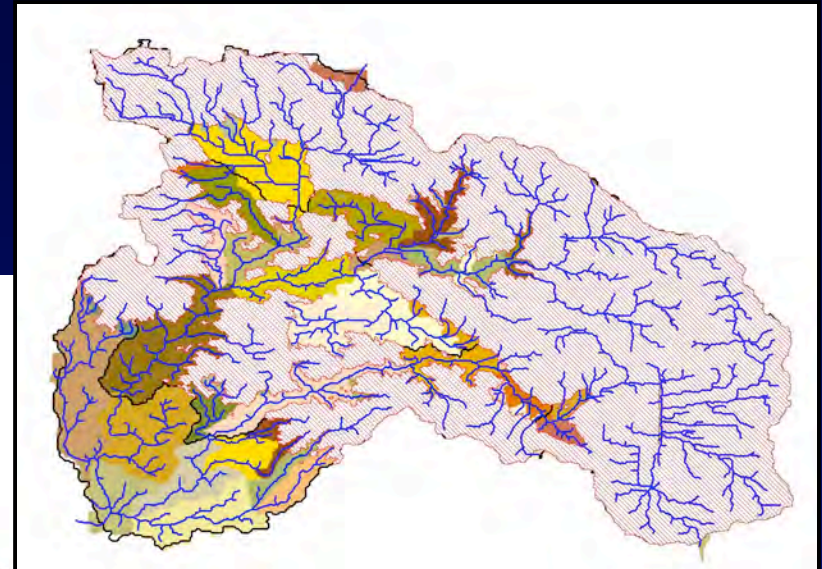
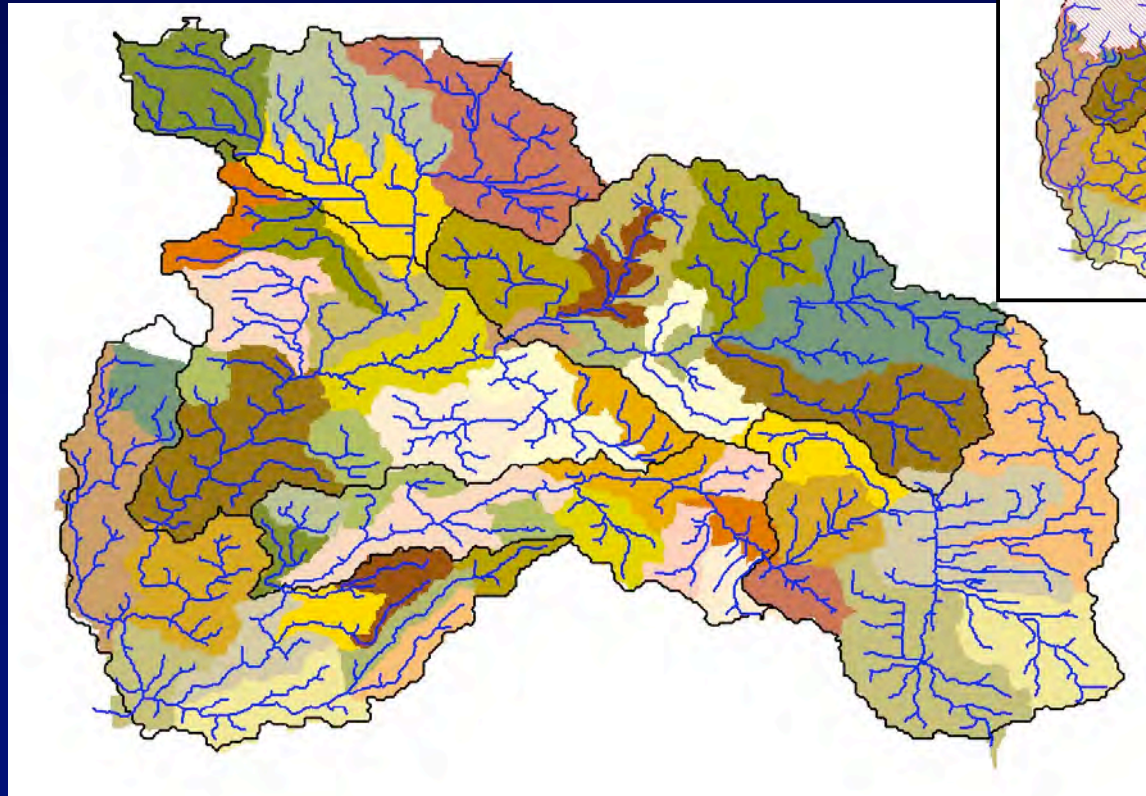


INFORM Region and Major Basins

INFORM DATA INVENTORY CNRFC STREAMFLOW RECORDS

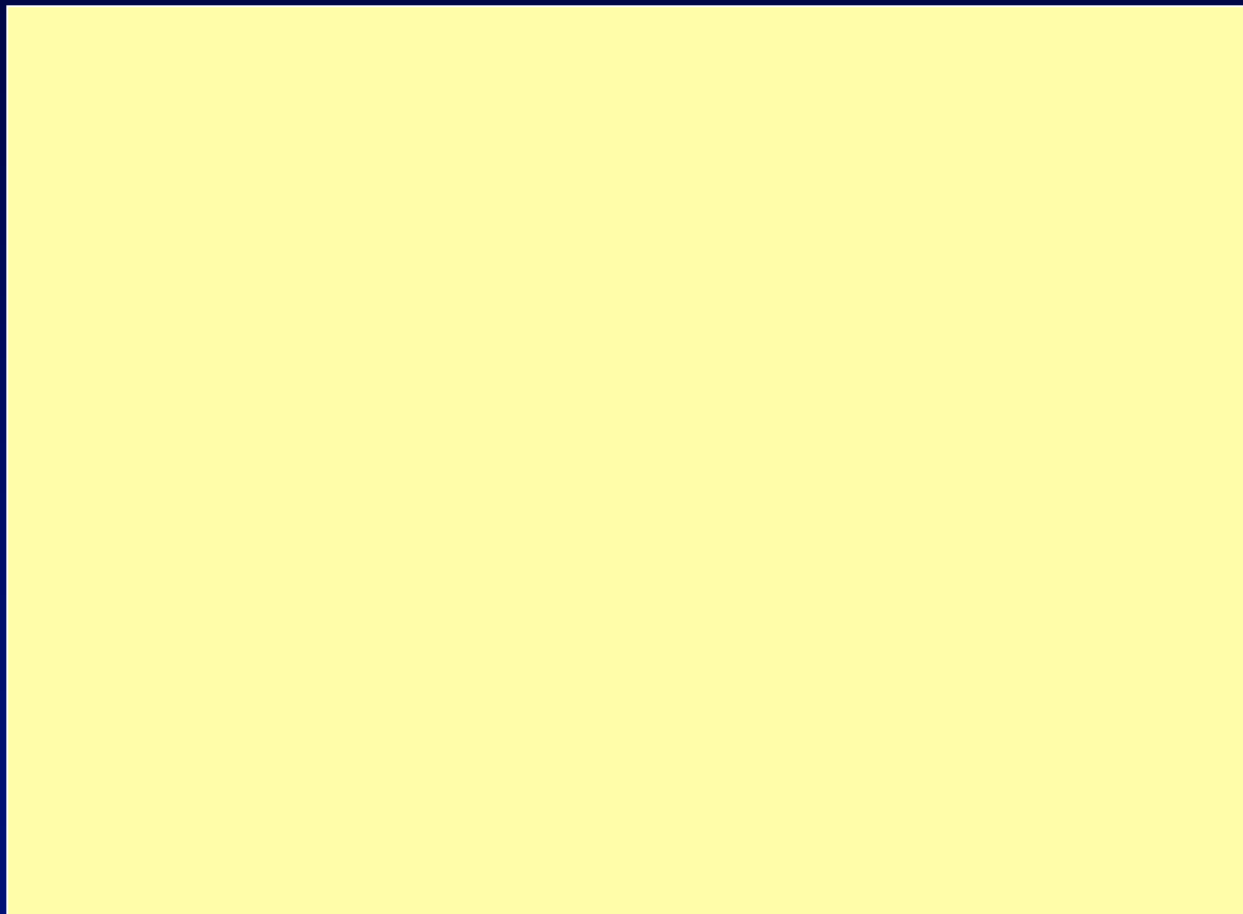


Distributed Tributary Basin System for Oroville – Example for INFORM Hydrology Modeling



Examples of Hydrologic Performance Analysis – Daily Scatterplots – Box-Cox transformed flows

OROVILLE



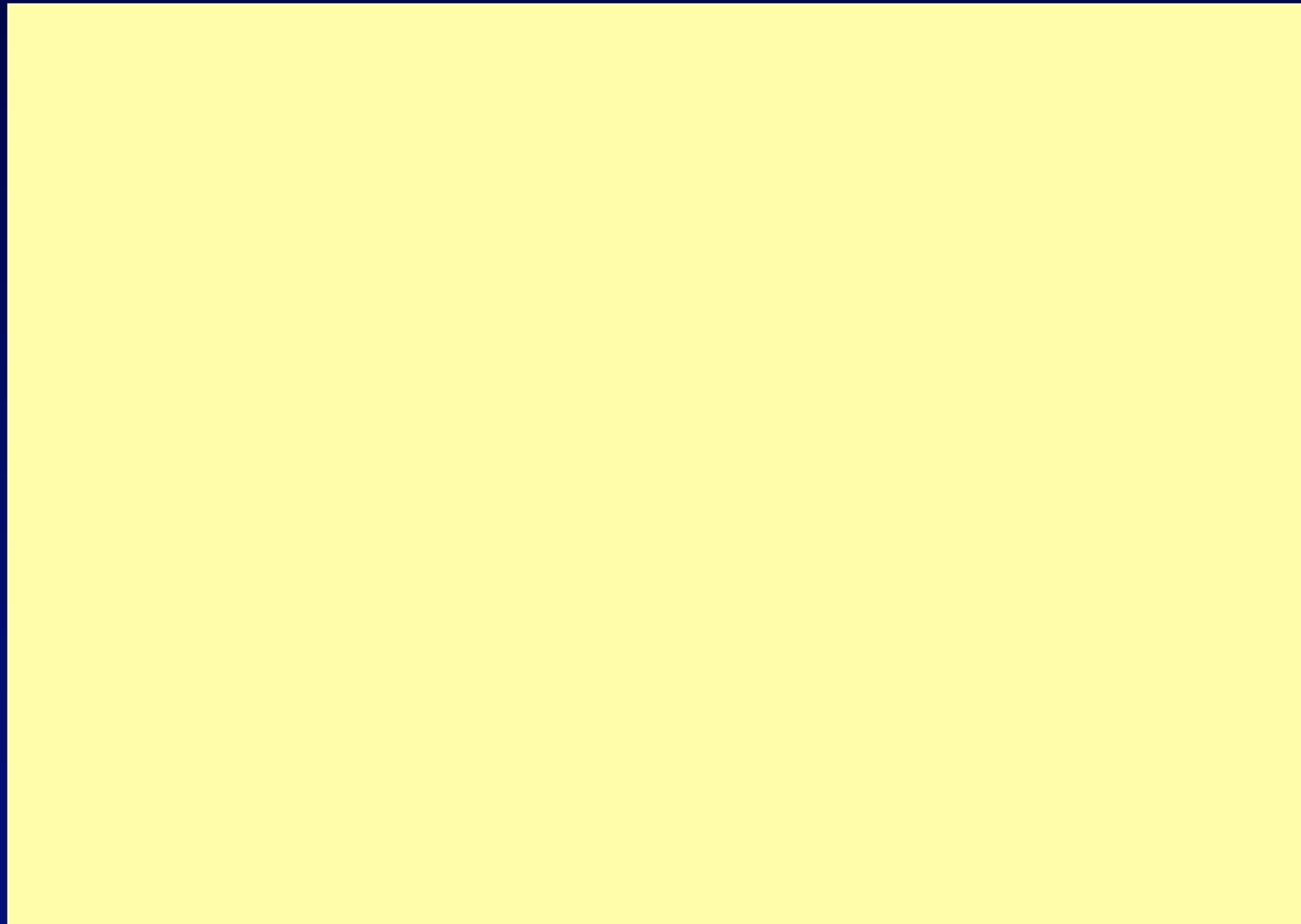
Overall Hydrology Model Performance Statistics Daily Inflow

	ρ	<i>RMSE (cms)</i>	<i>FDAE</i>	<i>Water Years</i>
Folsom	0.94	74.3	0.3	10/1/1960 - 9/30/1999
Oroville	0.92	117.9	0.32	10/1/1960 - 9/30/1997
Trinity	0.93	31.2	0.32	10/1/1963 - 9/30/1999
Shasta	0.94	105.2	0.25	10/1/1960 - 9/30/1992

Examples of Hydrologic Performance Analysis

– Time Series

OROVILLE DAILY FLOW - CMS



Examples of Hydrology Performance Analysis – Exceedance Frequency

Folsom

Oroville

Box-Cox transform

where λ is set to 0.3

Trinity

Shasta

Examples of Hydrologic Performance Analysis Monthly Climatology

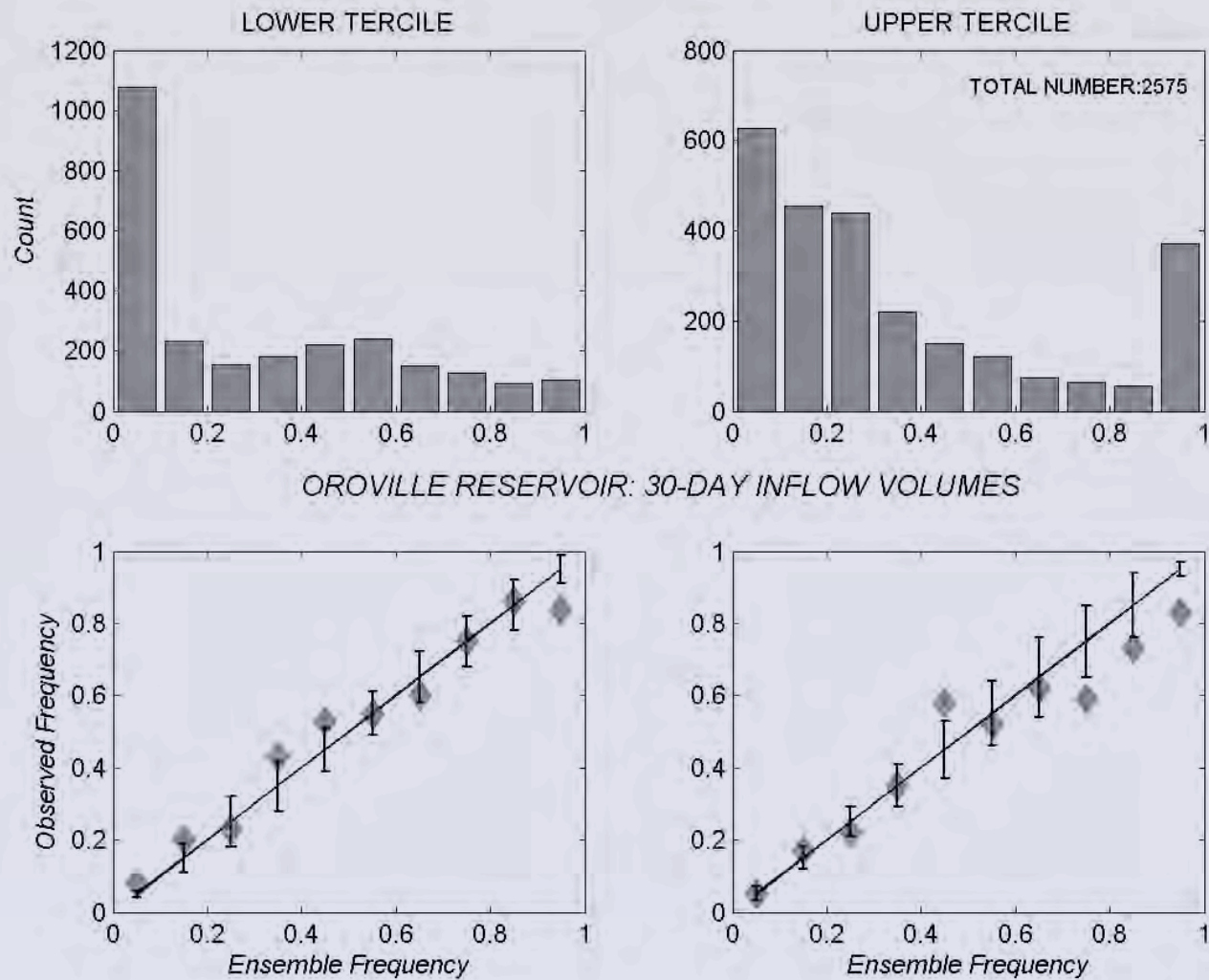
Folsom

Oroville

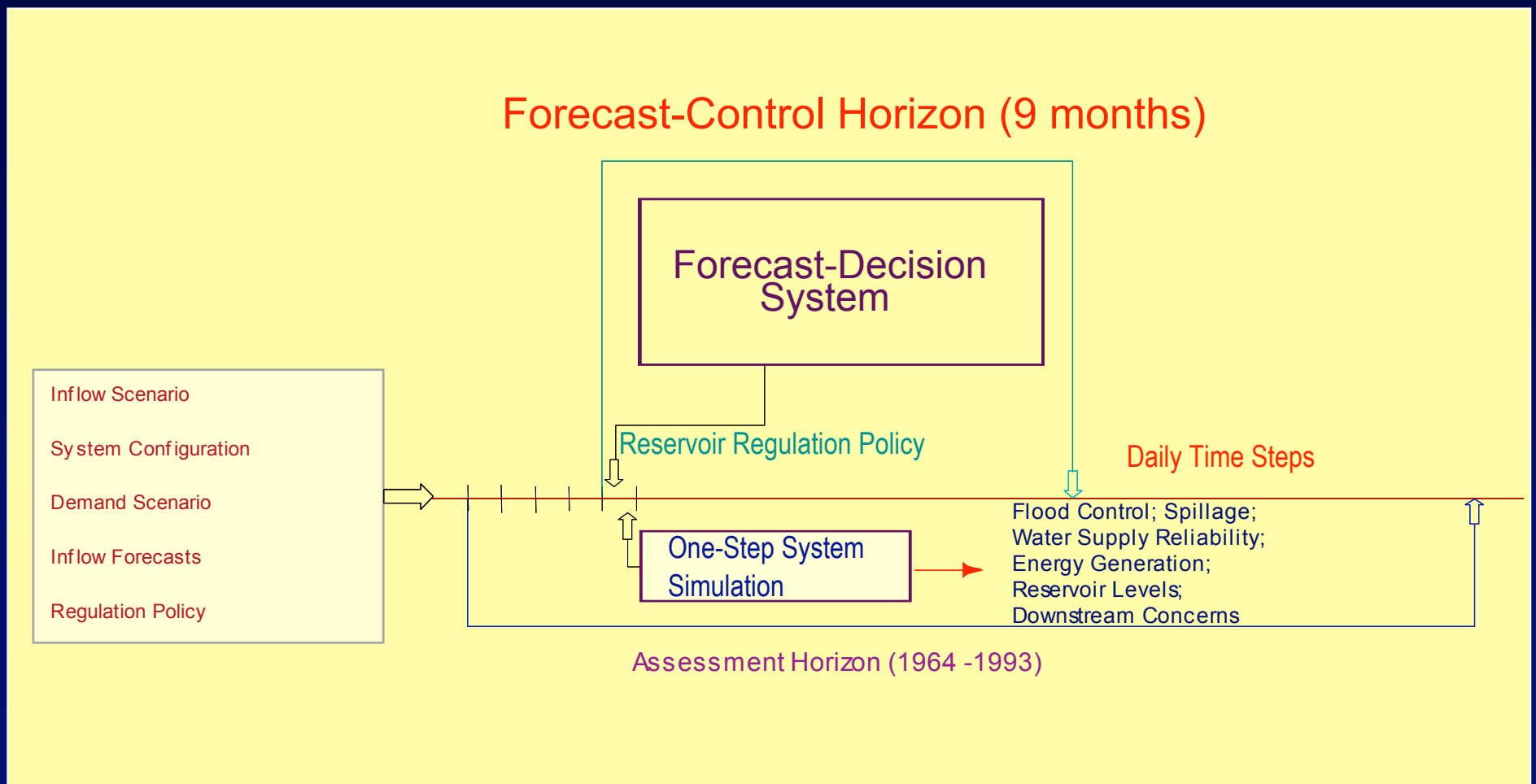
Trinity

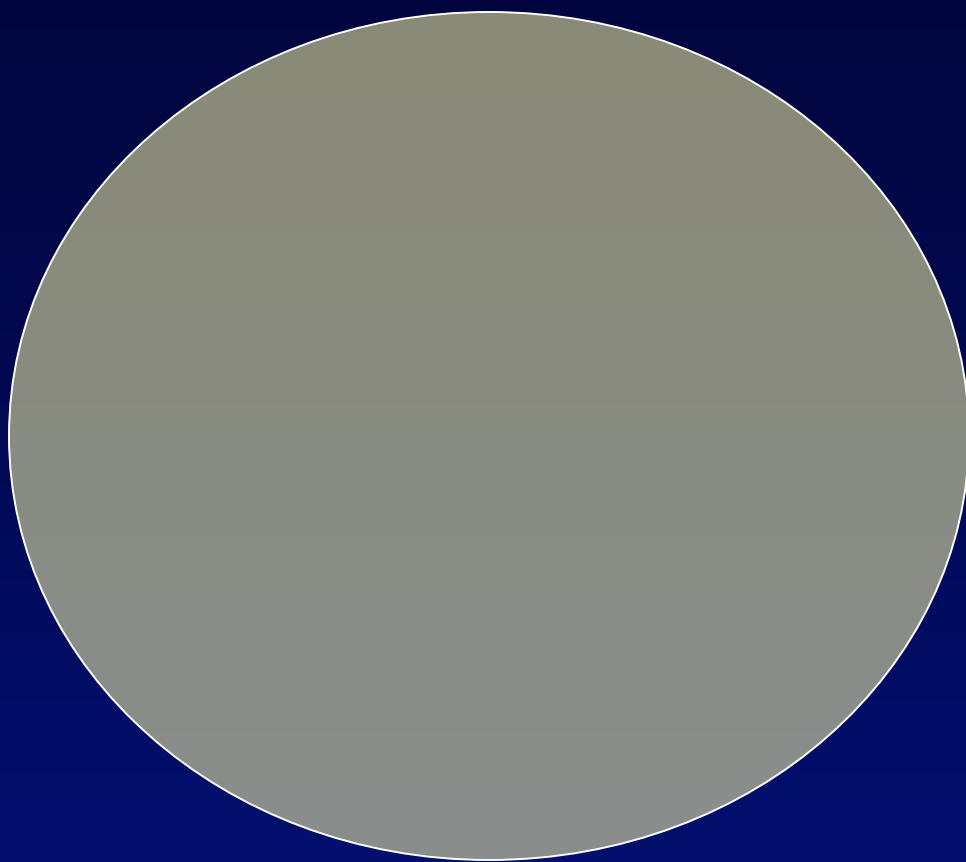
Shasta

SAMPLE RELIABILITY DIAGRAMS



MULTI-RESERVOIR – MULTI-OBJECTIVE DECISION MODEL





MULTIOBJECTIVE RESERVOIR DECISION MODEL

Reservoirs	Parameters	Forecasting Models		
		Ensemble	Deterministic	Perfect Foresight
Folsom	Inflow (cfs)	3,558	3,558	3,558
	Spillage (cfs)	188	353	161
	Energy (GWH)	1.89	1.91	2.02
	Max. Release (cfs)	99,905	121,841	59,968
	Max. Damage (\$)	0	842,000,00 0	0
Oroville	Inflow (cfs)	4,992	4,992	4,992
	Spillage (cfs)	218	251	119
	Energy (GWH)	5.06	5.06	5.12
	Max. Release (cfs)	155,057	156,945	92,563
	Max. Damage (\$)	0	0	0
Shasta	Inflow (cfs)	8,571	8,571	8,571
	Spillage (cfs)	374	582	252
	Energy (GWH)	7.27	7.40	7.62
	Max. Release (cfs)	161,532	161,532	101,338
	Max. Damage (\$)	0	0	0
Trinity	Inflow (cfs)	1,936	1,936	1,936
	Spillage (cfs)	115	150	110
	Energy (GWH)	1.23	1.21	1.19
	Max. Release (cfs)	72,560	72,560	61,073
	Max. Damage (\$)	0	0	0

Conclusion of Hydrologic Performance Analysis

- Hydrology models performed well and captured the hydrologic response with respect to timing and magnitude, and for various temporal scales
- Performance similar to operational CNRFC model running with the same parameters (but offers use of higher resolution input).
- Ensemble Streamflow Predictions (ESP) validated over historical horizon for all reservoir sites
- Decision component w/ ESP showed improved conservation without significant reduction in flood control and energy production benefits

INFORM SYSTEM - FUTURE PLANS

- Quasi-operational testing and assessment begins - November 2005
- Use the INFORM structure for assessing impacts of climate change and increased demand on management alternatives
 - * How can the reservoir system meet demands for conservation, flood control, downstream objectives and energy production
 - * Scenario operations simulations for training and preparation ...